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ENGINEER RESEARCH AND DEVELOPMENT CENTER, CORPS OF ENGINEERS
COASTAL AND HYDRAULICS LABORATORY
WATERWAYS EXPERIMENT STATION, 3909 HALLS FERRY ROAD
VICKSBURG, MISSISSIPPI 39180-6199

REPLY TO
ATTENTION OF

April 4, 2003

United States Environmental Protection Agentcy

Craig Zeller
United States Environmental Protection Agency
Region 4
Atlanta Federal Center
61 Forsyth Street
Atlanta, GA 30303-8960

Dear Mr Zeller,

Enclosed is the final report describing the impacts of in-stream dam removal on the morphology of Twelve Mile Creek This work was performed by the Engineer Research and Development Center (ERDC), Waterways Experiment Station (WES), under a Cooperative Research and Development Agreement (CRADA) with Schlumberger Limited If you have any questions concerning the report, please call me at (601) 634-2371

Sincerely,

Stephen H Scott, PhD, PE
Research Hydraulic Engineer
ERDC-WES

Enclosure

IMPACT OF IN-STREAM DAM REMOVAL ON THE MORPHOLOGY OF TWELVE MILE CREEK

By

Stephen H. Scott

Engineer Research and Development Center
Waterways Experiment Station
U.S. Army Corps of Engineers

February 2003
Final Report

Prepared for Schlumberger Limited

IMPACT OF IN-STREAM DAM REMOVAL ON THE MORPHOLOGY OF TWELVE MILE CREEK

INTRODUCTON

Twelve Mile Creek originates North of Pickens, South Carolina, with a watershed area of approximately 140 square miles (Bechtel 1993). The upstream reach of Twelve Mile Creek north of Pickens is characterized by a meandering, relatively slow moving stream. South of Pickens near Liberty, South Carolina, the stream valley begins to narrow and steepen, with the creek resembling a mountain stream with exposed rocks, swift moving water, and abundant riffles. The first in-stream dam on Twelve Mile Creek, the Easley Central water supply reservoir, is located approximately 4 miles downstream of the Liberty Bridge highway crossing. Two additional dams, Woodside I and Woodside II, are located approximately 0.7 and 1.7 miles downstream of Easley Central dam respectively. The pools behind the three in-stream dams are approximately 150 - 200 feet in width and 200 - 300 feet in length. Bedrock overlaid by sediment is located along this steep 1.7- mile reach of Twelve Mile Creek. The sediment thickness tends to increase as the channel approaches the dam backwater.

The channel below Woodside II flows into Lake Hartwell, a Corps of Engineers impoundment. The Lake Hartwell backwater is located approximately 1.5 miles downstream of Woodside II. At this location, coarse sediment load from Twelve Mile Creek is deposited, with the finer silt and clay sediment fractions depositing further into Lake Hartwell. All of the coarse sediments are trapped in the channel extending approximately 2.0 miles below the upper limit of the Lake Hartwell headwater

A capacitor manufacturing plant operated by Sangamo Weston, Inc discharged PCBs into the Twelve Mile Creek drainage basin and ultimately into Lake Hartwell. The Sangamo Weston plant was designated as a Superfund Site by EPA and split into two Operable Units and includes the former plant site and six satellite disposal areas. Operable Unit two (OU2) addresses the surface water, sediment, and biological migration pathways downstream of the plant site. Schlumberger has conducted investigation and cleanup work at OU1 and OU2 as directed by EPA and is currently negotiating the overall damages to Twelve Mile Creek and Lake Hartwell with a group of designated Natural Resource Trustees. One potential settlement scenario involves removal of the three in-stream dams to restore Twelve Mile Creek to its natural free-flowing condition as a steep, swift flowing stream with numerous pools and riffles. The fate of the sediment trapped behind the dams is a major concern when considering dam removal. This report presents the results of a numerical model study of the fate and transport of sediments behind the three in-stream dams and within the associated channels.

BACKGROUND

Two previous sediment fate and transport modeling studies were conducted on Twelve Mile Creek. Bechtel (1993) evaluated the fate and transport of sediments released from the lowermost dam (Woodside II) into the Lake Hartwell headwaters. This study utilized HEC-6, a one-dimensional sediment transport model developed by the U.S. Army Corps of Engineers. The model results indicated that the lower Twelve Mile Creek channel just below the intersection with the Lake Hartwell backwater trapped all of the sand sized sediments. A second study (Scott 2000) was initiated to determine the fate and transport of sediments sluiced and dredged from the lower reservoir, and to validate model predictions of sediment thickness over a ten-year interval (1990 – 2000). Again, HEC-6 was used to show change in channel morphology below Woodside II due to the dredging and sluicing of sediments. Results indicated that short-term impacts to the lower Twelve Mile Creek channel would occur (deposits of sediment), but that the sediment will transport to the lower channel over approximately one years duration. Validation of the model by comparing the change in bed elevation from 1993 and 2000 surveys was inconclusive, with the exception of the area of maximum deposition (transect Q) where model results and the survey data compared well.

The effort described in this report details the impacts of removing the three in-stream dams on channel morphology. A more recent version of HEC-6 was used for this study (HEC-6T). This version has the capability to simulate channel widening as a function of bed scour.

OBJECTIVES

The objectives for the effort described in this report are as follows:

1) Evaluate the fate and transport of sediments in the Twelve Mile Creek channel after the three in-stream dams are removed
2) Estimate the quantity of sediments mobilized in each section of the channel
3) Estimate the quantity and spatial distribution of sediment in the lower Twelve Mile Creek channel below Woodside II
4) Recommend a dam removal strategy based on the modeling scenarios
5) Evaluate long term and short term impacts of transported sediment

FIELD DATA COLLECTION EFFORTS

Additional field data were collected to support the modeling effort. Field data were collected for the previous modeling efforts on Twelve Mile Creek (Bechtel 1993 and RMT 2000). In 1990, Channel geometry was surveyed at selected locations along Twelve Mile Creek and the Twelve Mile Creek arm of Lake Hartwell. In 2000, approximately the same locations were re-surveyed. In addition to survey data, bed samples were collected along the entire study reach. For the previous studies, the upstream boundary of the model was the Woodside II reservoir, and the downstream boundary was Lake Hartwell at Clemson, South Carolina. For the dam removal study, the upstream boundary was moved to the Liberty Bridge highway crossing approximately six miles upstream from Woodside II. Additional channel geometry surveys were conducted along this reach, including surveys in the pools behind the dams. Additionally, sediment samples were taken in the pools and sections of channel between the dams. A good description of the most recent field data collection effort is provided by RMT (RMT 2002), along with cross section geometries and bed sample particle size distributions. Table 1 presents transects where channel geometry was measured, along with the cumulative distance from the downstream boundary (Lake Hartwell at the Southern Railroad crossing at Clemson). The modeling effort utilized the 2000 survey data and bed sediment sample particle size distributions for all transects below Woodside II. Figures 1 – 4 show the approximate locations of the channel transects on a US Geological Survey map. The previous modeling efforts indicated that all of the coarse grained sediments (sands) were deposited in the reach between transect O and T16 (Figure 2). It is generally recognized that the influence of the Lake Hartwell headwater on Twelve Mile Creek hydraulics occurs up to transect W10 (Figure 3). Figure 4 depicts the three in-stream dams and the survey transects between the dams. Four survey transects were taken in the pool behind each dam (not shown on Figure 4). The upstream boundary extends up to the Liberty Bridge highway crossing located approximately 3.2 miles above transect 11C. Cross section geometry for transects 12C and 13C in Table 1 were estimated based on the channel geometry at Liberty Bridge (the USGS gaging station) and transect 11C. These transects are not shown on Figure 4. In addition to channel geometry, the depth of sediment was measured in all the pools and channels from Woodside II to transect 11C. The depth of sediment was estimated for transects 12C, 13C, and Liberty Bridge. Table 2 presents the depth of sediment to bedrock.

MODEL DESIGN

To facilitate the computation of the change in sediment volume from the pools and channels behind the dams, the geometric data set in the model was subdivided into seven channel reaches or segments. These segments are described in Table 3, along with the respective inclusive transects. The resulting change in sediment volume is reported in terms of these channel segments.

Sediment Rating Curve

The upstream boundary of the earlier HEC-6 modeling efforts was the Woodside II reservoir. The sediment-rating curve used for computing the naturally inflowing sediment into Twelve Mile Creek was constructed using measured suspended solids data (Bechtel 1993). For the dam removal simulations, the upstream boundary was moved to the Liberty Bridge highway crossing, approximately six miles upstream. Because no measured suspended sediment data were available for flows at this boundary, a sediment rating curve was created by the use of SAM, a computer program used to compute channel transport capacity for a given sediment size (SAM 2000). The program input includes the cross section geometry, the size distribution of the sediment, a series of discharges, channel roughness, and bed slope. Program output is tons of sediment as a function of discharge, with each size fraction of the sediment represented. The sediment-rating curve was computed for the Liberty Bridge channel geometry and bed sediments. The rating curve is found in Figure 5, with the sediment size fraction presented in Figure 6.

Model Time Step and Channel Roughness

The removal of a dam creates a large slope between the upstream and downstream bed. The channel will tend to adjust the upstream bed elevation accordingly by incising and lowering the channel until an equilibrium condition is met. For this equilibrium condition to occur, the hydrodynamic forces that tend to erode and transport a particle are balanced by the forces tending to keep the particle in place. The resulting flow and erosion adjustment processes are very dynamic over a short distance, with change in bed elevation rapidly occurring. Modeling such a dynamic event requires a careful evaluation of model time step. Through trial and error simulations, the appropriate time step for the Twelve Mile Creek study was determined to be 0.005 hour. Additionally, the rate of erosion is highly dependent on bed roughness. For the previous studies of Twelve Mile Creek sediment transport, a roughness value of 0.03 Manning n was assigned to the channel. For this study, a variety of channel reaches were involved. For the reaches with a relatively smooth sand bed, a Manning n of 0.03 is probably representative. For channel reaches that are steep with exposed rock and fast water, a higher roughness value may be required. A number of simulations were conducted with varying values of Manning n in the channel and behind the dams. The results indicated that although channel roughness did make some difference in sediment transport, the overriding influence on erosion rate and resulting change in bed morphology was the steep channel slope resulting from the dam removal. Therefore, a single value of Manning n, 0.03, was used in all channel reaches.

Boundary Conditions

The flow was input into the model at the upstream Liberty Bridge boundary. The downstream boundary was the stage at Lake Hartwell at transect T6. The flow duration for each dam removal scenario was 1.25 years. This flow record consisted of an initial 90 days at 200 cfs and a 365-day flow hydrograph represented by the 1990 flow record measured at the Liberty Bridge gaging station. The respective downstream stage boundary was 659 ft msl for the 90-day mean discharge and the associated Lake Hartwell stage for the year 1990. The 90-day mean discharge was used as the initial flow to insure model stability during the most dynamic portion of the dam removal simulation. The additional one-year flow simulation was conducted because the discharge events that form the channel geometry are the higher peak flow events resulting from storms in the Twelve Mile Creek watershed. After the final dam was removed (Easley Central), a 9-year simulation was conducted to evaluate the fate of material deposited below Woodside II. The flow and stage boundary conditions are presented in Figures 7, 8, 9, and 10.

The depth of sediment in each cross section was determined from the soundings taken behind the dams and in the channel reaches during the field data collection effort (Table 2). A non-erodible boundary was specified for each cross section in the model based on the bed thickness measurements with the exception of transect 6C. The measured sediment thickness was six inches, which is much less than the adjacent downstream and upstream transect measurements (152 and 86 inches respectively). Because of the possibility that this may be an anomaly based on the location of the sample, the sediment depth in the model was assumed to be 86 inches at transect 6C.

SIMULATIONS

The dam removal scenario is as follows:

1) The first dam removed is Woodside II. The 1.25-year flow event described above is simulated with the dam removed. The channel segments involved in this simulation are segment 1 (transects T6 – T19), segment 2 (transects WSII – T1 – T4), and segment 3 (transects 1C – 4C). The Woodside I dam acts as a hard point in the channel with no bed change in the upper transects.

2) The channel geometry change resulting from the removal of Woodside II (segments 1, 2, and 3) is incorporated in the Woodside I simulation. The 1 25-year flow event is simulated with the dam removed. The channel segments involved in this simulation are segments 1, 2, 3, segment 4 (transects WSI – T1 – T4), and segment 5 (transects 5C – 8C). The Easley Central dam acts as a hard point in the channel thus bed change does not occur in the upper transects. The cumulative time from the removal of Woodside II is now 2.5 years.

3) The channel geometry change resulting from the removal of Woodside I (segments 1, 2, 3, 4, 5) is incorporated into the Easley Central simulation. The 1.25-year flow event is simulated with the dam removed. The channel segments involved in this simulation are segments 1, 2, 3, 4, 5, segment 6 (transects EC – T1 – T4), and segment 7 (transects 9C – Liberty Bridge). The cumulative time from the removal of Woodside II is now 3.75 years.

4) The Easley Central simulation is then extended out an additional 9 years to gauge the response of the lower Twelve Mile Creek channel (T19 – T12) to long-term hydrodynamics. The cumulative time from the removal of Woodside II is now 12.75 years.

RESULTS

The Twelve Mile Creek pre-simulation bed elevation profile is presented in Figure 11, along with the bedrock profile. The bedrock profile was estimated below Woodside II (transects T12 – T19) and above transect 11C. Results from the removal of Woodside II are found in Table 4 and Figure 12. Approximately 8,857 cubic yards of sediment eroded from the pool behind the dam, with 132,970 cubic yards mobilized from the channel between Woodside II and Woodside I. Approximately 4,402 cubic yards of sediment passed through the system over the 1.25-year timeframe. A total of 146,229 cubic yards of sediment were transported to reaches below Woodside II. The final bed profile is presented in Figure 12 along with the initial bed and bedrock profiles. A maximum of approximately 7.0 feet of sediment is deposited at transect T18, just downstream of Lay Bridge, with bed sedimentation occurring downstream to about transect T16. Some sediment deposits remain in the channel between Woodside I and II (transects 1C – 3C). The change in bed elevation for 90 and 455 days for segments 1-3 is found in Appendix A.

Results from the removal of Woodside I dam are presented in Table 5 and Figure 13. Approximately 2,694 cubic yards of sediment were removed from the pool behind the dam, with 41,559 cubic yards of sediment mobilized from the channel between Woodside I and Easley Central. Approximately 15,000 cubic yards of sediments that remained in the channel between Woodside II and Woodside I were mobilized, with an additional 7,826 cubic yards of inflowing sediment passing through the system over the 1.25-year simulation. A total of 67,228 cubic yards was passed to the channel below Woodside II. The cumulative total volume of sediment passed below Woodside II is 213,457 cubic yards after 2.5 years of simulation. Figure 13 shows the final bed profile, along with the bed profile resulting from the Woodside II removal simulation. The majority of the channel sediments have been mobilized from Easley Central reservoir to below Woodside II. Approximately 8.0 feet of sediment has been deposited at transect T18, just downstream of Lay Bridge, with bed sedimentation occurring downstream to transect T15, which is just upstream of Maw Bridge. The change in bed elevation for 90 and 455 days for segments 1-5 is found in Appendix B.

The results for the removal of Easley Central are found in Table 6 and Figure 14. Approximately 4,049 cubic yards of material were eroded from the pool behind the dam, with 47,738 cubic yards mobilized from the channel upstream of the dam. Some deposition occurred in the channel between Woodside I and Easley Central (1,419 cubic yards) and in the channel between Woodside II and Woodside I (1,646 cubic yards). The system sediment transport was approximately 24,458 cubic yards, with a total of 73,180 cubic yards transported to the channel below Woodside II. The cumulative volume of sediment passed below Woodside II is 286,637 cubic yards after 3.75 years of simulation. Figure 14 depicts the final bed profile along with the bed profile resulting from the Woodside I simulation. Approximately 9.0 feet of sediments have deposited at transect T18, just downstream of Lay Bridge. For the most part, the reach of channel from Easley Central to Woodside II has been scoured to bedrock. Figure 15 presents the pre-simulation bed elevation; along with the final bed elevation after all three dams have been removed (3.75 year duration). The change in bed elevation for 90 and 455 days for segments 1-7 is found in Appendix C.

The model was run for an additional nine years to evaluate the change in channel morphology below Woodside II as a function of a long-term hydrograph. The results are found in Figure16 for transects T12 – T19. The final bed elevation (12.75 years) is plotted along with the bed elevation just after all dams were removed (3.75 years). The results of this simulation indicate that the sediment deposits are eroding and gradually migrating into the Lake Hartwell headwaters.

A summary of the percentage of sediment eroded from each segment is found in Table 7. Approximately sixty two percent of the total sediment eroded from the channels originated from the Woodside II pool and upstream channel. The percentage of sediment eroded from the Woodside I and Easley Central pools and associated channels was approximately 21 and 17 percent respectively.

DISCUSSION

The simulations indicate that the reservoirs and associated channels will potentially scour to bedrock within a year of dam removal. The first 90 days of the simulations were conducted at a mean discharge of 200 cfs. The actual discharge record in the winter or spring of the year will include storm events which can have peak flows up to ten to twenty times greater than the mean flow. During these peak-flow events when the channel is flowing full, the bed is actively changing and sediment transport is at a peak. The mean flow scenario is therefore conservative and thus the erosion rate of bed sediments after dam removal may be considerably higher depending on the time of year.

The most significant impact on the Twelve Mile Creek system from dam removal activities is for channel reaches below Woodside II between transects T19 and O. The simulations estimate that approximately 286,000 cubic yards of material will deposit in the lower reaches, with initial deposits occurring just downstream of Woodside II, and eventually migrating into the headwater of Lake Hartwell (channel reach bracketed by transects O and W10). Sediment deposits of up to 9 feet thick are indicated in the vicinity of Lay Bridge. The inflowing sediment load from the boundary is estimated based on sediment carrying capacity calculations. Because Twelve Mile Creek has a bedrock foundation, there may not be an unlimited sediment supply to the stream. Therefore, the sediment-rating curve utilized in this study may over-estimate the amount of sediment entering the stream as a function of discharge.

The excessive sediment deposits below Woodside II can have a serious impact on the environment, adjacent infrastructure, and water surface elevations. The in-stream habitat will be immediately impacted, with all existing pool and riffle sequences covered. Sediment deposits up to 9 feet or greater in thickness will potentially cover existing in-stream vegetation and adjacent over-bank vegetation and terrestrial habitat. The structural integrity of infrastructure such as Lay Bridge will need to be evaluated before dam removal. Water surface elevations along the reaches below Woodside II will be significantly higher, thus potentially inundating adjacent property and limiting access to the creek. Recreational activities such as fishing or boating will not be possible.

Although the initial impacts are severe to the reaches downstream of Woodside II, with time, the sediments will migrate into the headwater of Lake Hartwell. A shallow channel will form through the newly deposited sediments and vegetation will colonize the delta areas adjacent to the channel.

CONCLUSIONS AND RECOMMENDATIONS

- The channel between the dams will scour to bedrock, restoring the creek system to pre dam conditions. Based on model results, it is estimated that this will occur within one year of dam removal

- The sediments eroded from the pools above the dams and the associated channels will initially deposit below Woodside II, with the largest deposits located in the channel reach bracketed from T19 – T16. Model results estimate that sediment depths of up to 9 feet may occur in some areas.

- It is recommended that the dams be removed in one-year intervals, beginning with the lowermost dam, Woodside II. Modeling results indicate that sixty two percent of the sediments available for transport out of the Twelve Mile Creek channel will mobilize after Woodside II is removed. Delaying removal of Woodside I for a year will allow for the channel below Woodside I to stabilize and for remedial activities to commence in the lower reaches below Woodside II, if any are required.

REFERENCES

Bechtel (1993), "Remedial Investigation Report for the Sangamo Weston, Inc. / Twelve mile Creek / Hartwell Lake Site Operable Unit Two, Pickens County, South Carolina", Volumes I and II, May 1993.

RMT (1999), "Final Report Twelve Mile Creek Data Collection, Sangamo Weston, Inc. Operable Unit 2, Pickens County, South Carolina", December 1999.

RMT (2002), "Twelve Mile Creek Sediment Transport Model / Data Collection Report, Sangamo Weston, Inc. Operable Unit 2, Pickens County, South Carolina", November 2002.

Scott, S H. (2000), "ERDC Sediment Transport Studies on Twelve Mile Creek and Lake Hartwell in Support of the EPA Selected Remedy", April 2000.

WES (1998), "Hydraulic Design Package for Channels (SAM)", draft users guide, March 1998.

LIST OF TABLES

Table 1. Twelve Mile Creek transect locations

Transect	Distance from T6 - ft	Description
T6	0	Lake Hartwell at Southern Railroad Crossing – Clemson
H	3200	
I	5400	
J	7800	
K	8600	Lake Hartwell at Highway 133 Crossing
L	10500	
M	11800	
N	13900	
O	16500	Just Downstream from Madden Bridge
T12	18100	Just Upstream from Madden Bridge
P	19600	
Q	21300	
W7	23400	
T15	25500	Just Upstream from Maw Bridge
T16	27700	
W10	29200	
T17	30600	
W12	33300	
T18	34700	Just Downstream from Lay Bridge
T19	36600	Just Downstream from Woodside II
WSII – T1	37100	Woodside II – First Transect by Dam
WSII – T2	37200	
WSII – T3	37260	
WSII – T4	37360	Woodside II – Uppermost Transect
1C	37460	
2C	39620	
3C	40900	
4C	41800	Just Downstream of Woodside I
WSI – T1	42300	Woodside I – First Transect by Dam
WSI – T2	42420	
WSI – T3	42520	
WSI – T4	42590	Woodside I – Uppermost Transect
5C	43290	Channel Between Woodside I and Easley Central Dam
6C	44220	
7C	45320	
8C	45720	Just Downstream of Easley Central Dam
EC – T1	46220	Easley Central – First Transect by Dam
EC – T2	46290	
EC – T3	46350	
EC – T4	46440	Easley Central – Uppermost Transect
9C	46640	Channel Upstream of Easley Central
10C	47940	
11C	50440	
*12C	56100	
*13C	61770	
LIBERTY	67430	Liberty Bridge Gaging Station – Upstream Boundary

*** - Transect geometry estimated**

Table 2. Measurement of bed sediment depth from transect 11C to 1C

Location (transect)	Depth of Sediment to Bedrock (inches)[1]
11c	38"
Between 11c and 10c	68"
10c	61"
Between 10c and 9c	81"
9c	85"
7c	86"
6c	6"
5c	152"
Between 5c and 4c	157"
3c	25"
2c	127"
Between 2c and 1c	176"
1c	214"

[1]Note No depth measurements were taken at transects 8C and 4C These transects are located on bedrock near the base of the dams

Table 3. Model segments for sediment transport computations

Segment	Description	Transects	Distance – ft x 1000
1	Channel Below WSII	T6 – T19	0 – 36 6
2	WSII Reservoir	WSII T1 – T4	37 1 – 37 36
3	Channel Between WSII and WSI	1C – 4C	37 46 – 41 8
4	WSI Reservoir	WSI T1 – T4	42 30 – 42 59
5	Channel Between WSI and EC	5C – 8C	43 29 – 45 72
6	EC Reservoir	EC T1 – T4	46 22 – 46 44
7	Channel Above EC	9C - LIBERTY	46 64 – 67 43

Table 4. Estimated sediment quantities 1.25 years after Woodside II removal

Segment	Description	Change in Vol – yd^3	Cumulative Vol - yd^3
*	Inflowing Sediment	-4,402	-4,402
3	Channel Between WSII and WSI	-132,970	-132,970
2	WSII	-8,857	-8,857
1	Channel Below WSII	+146,229	+146,229

* - Sediment load from the upstream boundary
+ Deposition - Erosion

Table 5. Estimated sediment quantities 2.5 years after Woodside II removal (Woodside I removed)

Segment	Description	Change in Vol – yd^3	Cumulative Vol - yd^3
*	Inflowing Sediment	-7,826	-12,228
5	Channel Between WSI and EC	-41,559	-41,559
4	WSI	-2,694	-2,694
3	Channel Between WSII and WSI	-15,004	-147,974
2	WSII	-145	-9,002
1	Channel Below WSII	+67,228	+213,457

*- Sediment load from the upstream boundary
+ Deposition - Erosion

Table 6. Estimated sediment quantities 3.75 years after Woodside II removal (Easley Central removed)

Segment	Description	Change in Vol – yd^3	Cumulative Vol - yd^3
*	Inflowing Sediment	-24,458	-36,686
7	Channel Above EC	-47,738	-47,738
6	EC	-4,049	-4,049
5	Channel Between WSI and EC	+1,419	-40,140
4	WSI	0	-2,694
3	Channel Between WSII and WSI	+1,646	-146,328
2	WSII	0	-9002
1	Channel Below WS2	+73,180	+286,637

* - Sediment load from the upstream boundary
+ Deposition - Erosion

Table 7. Estimated volumes of eroded sediment from Twelve Mile Creek after 3.75 years

Segment	Description	Total Vol Eroded – yd^3	% Of Total Eroded Sediment
7	Channel Above EC	47,738	19 1
6	Easley Central	4,049	1 6
5	Channel Between WS1 and EC	40,140	16 1
4	WSI	2,694	1 1
3	Channel Between WSII and WSI	146,328	58 5
2	WSII	9,002	3 6

LIST OF FIGURES

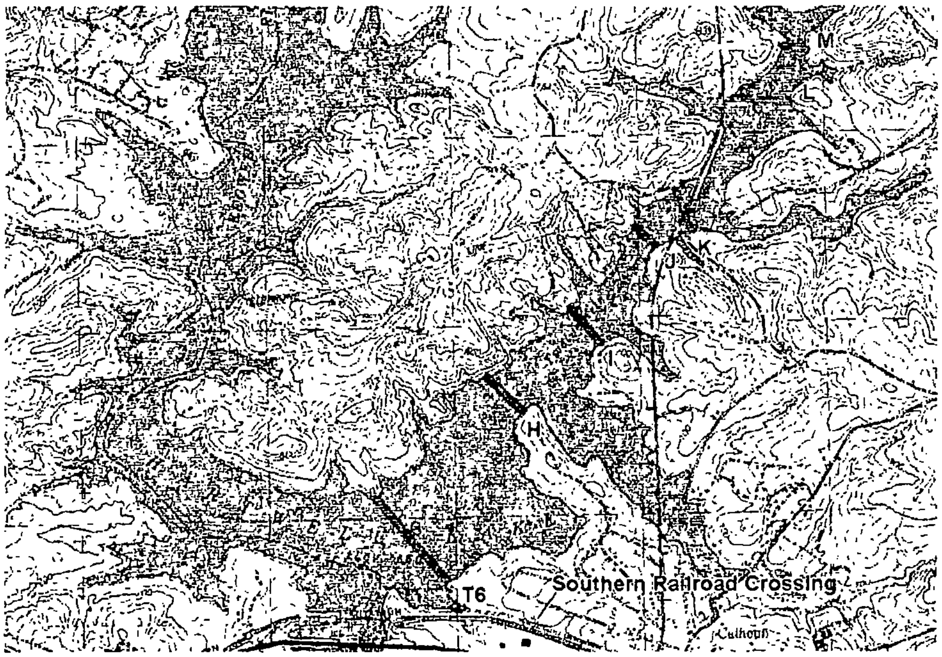

Figure 1. Lower Lake Hartwell channel geometry transects: T6 - M

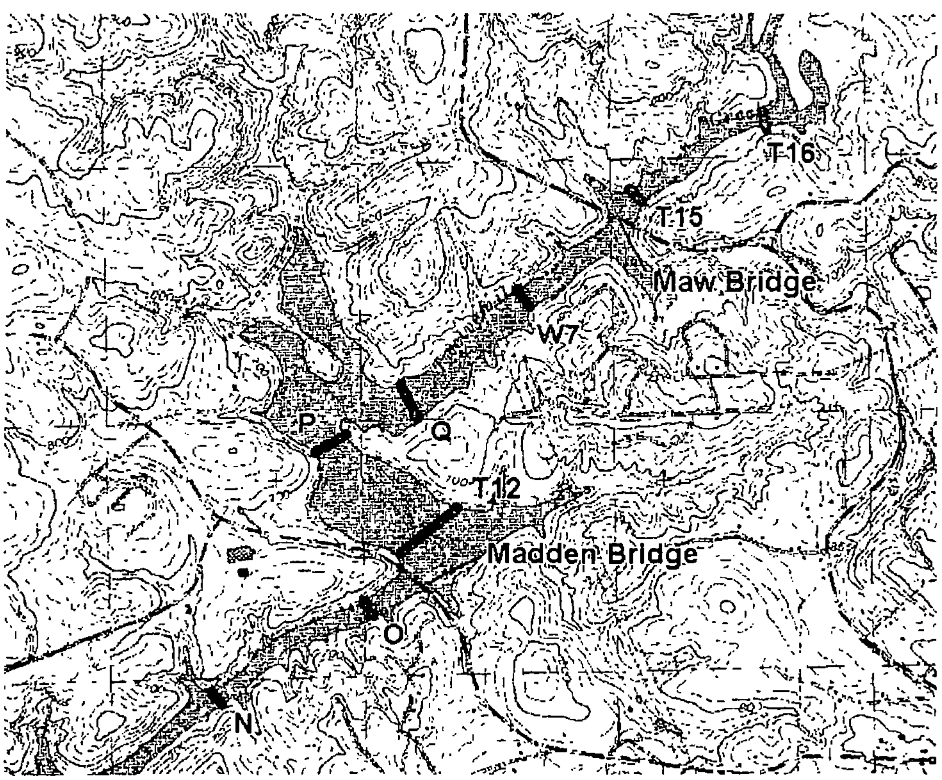

Figure 2. Upper Lake Hartwell channel geometry transects. N – T16

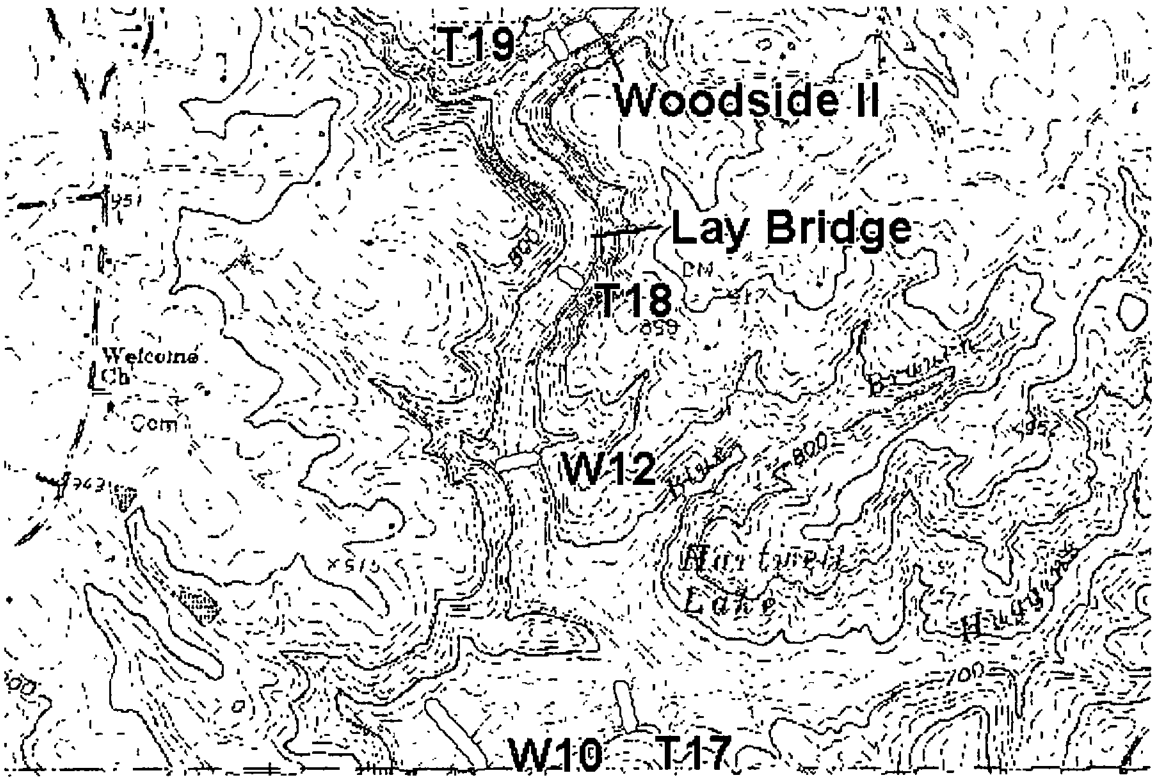

Figure 3. Lower Twelve Mile Creek channel transects: W10 – T19

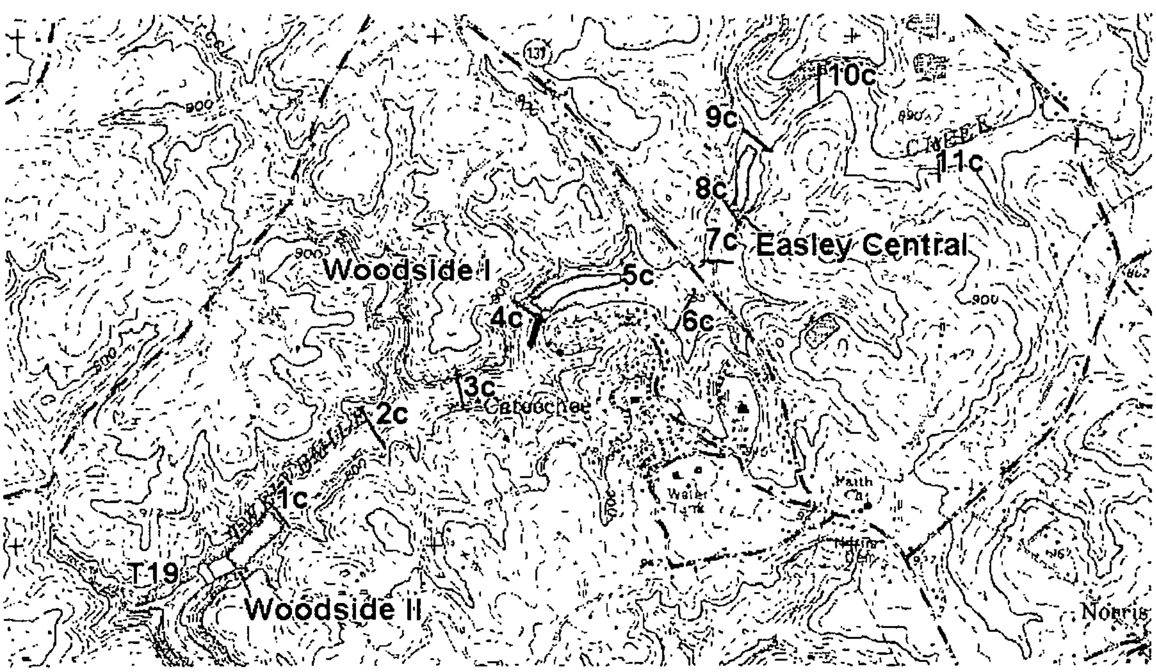

Figure 4. Upper Twelve Mile Creek channel geometry transects: 1C – 11C

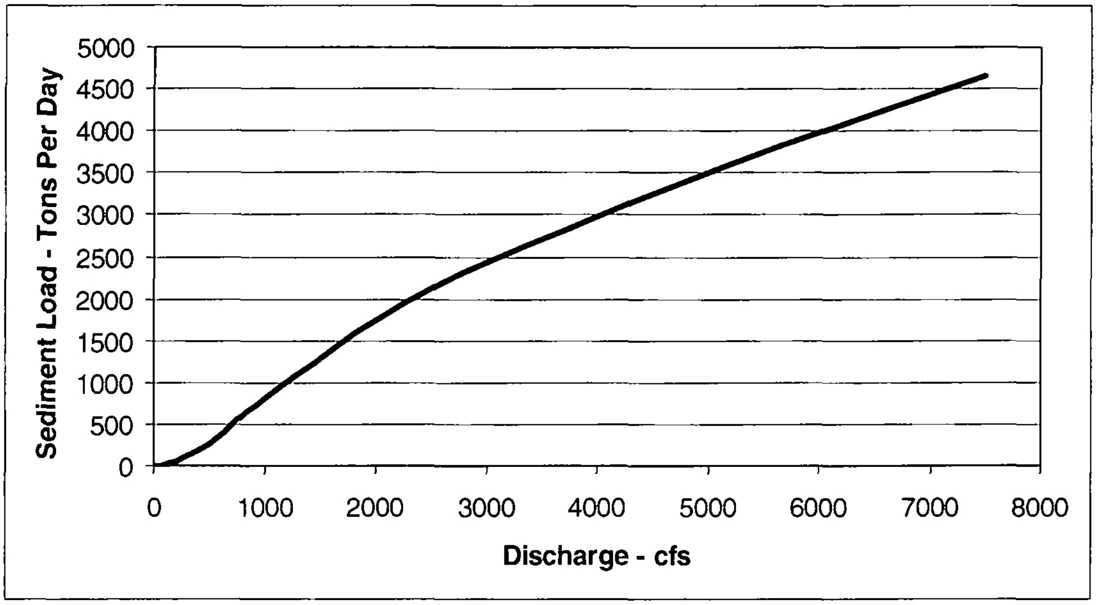

Figure 5. Sediment rating curve at Liberty Bridge

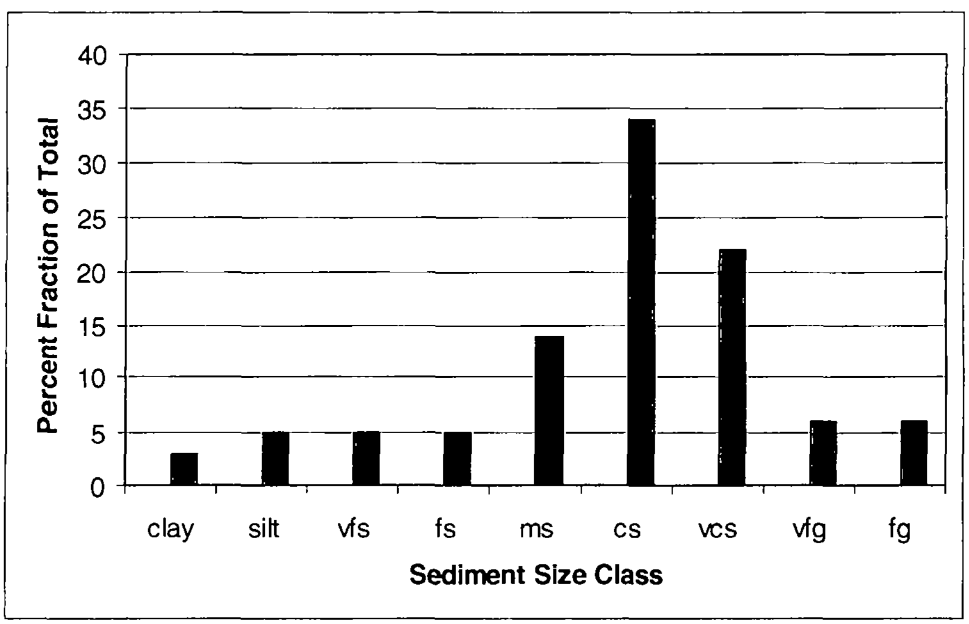

Figure 6. Sediment size fraction of bed sediments at Liberty Bridge:
vfs – very fine sand fs – fine sand ms – medium sand cs – coarse sand
vcs – very coarse sand vfg – very fine gravel fg – fine gravel

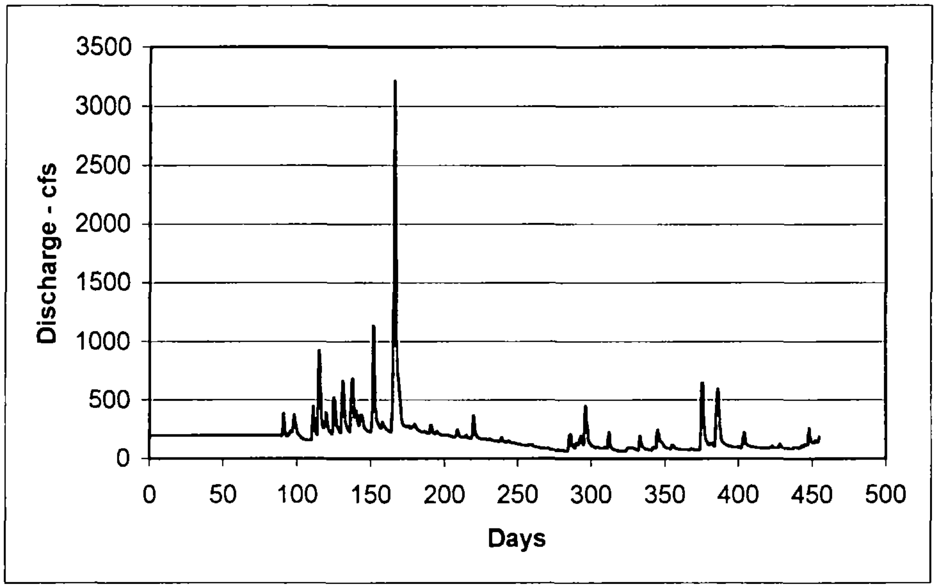

Figure 7. Upstream flow boundary condition at Liberty Bridge – initial 90 day 200 cfs mean flow with the 1990 yearly hydrograph

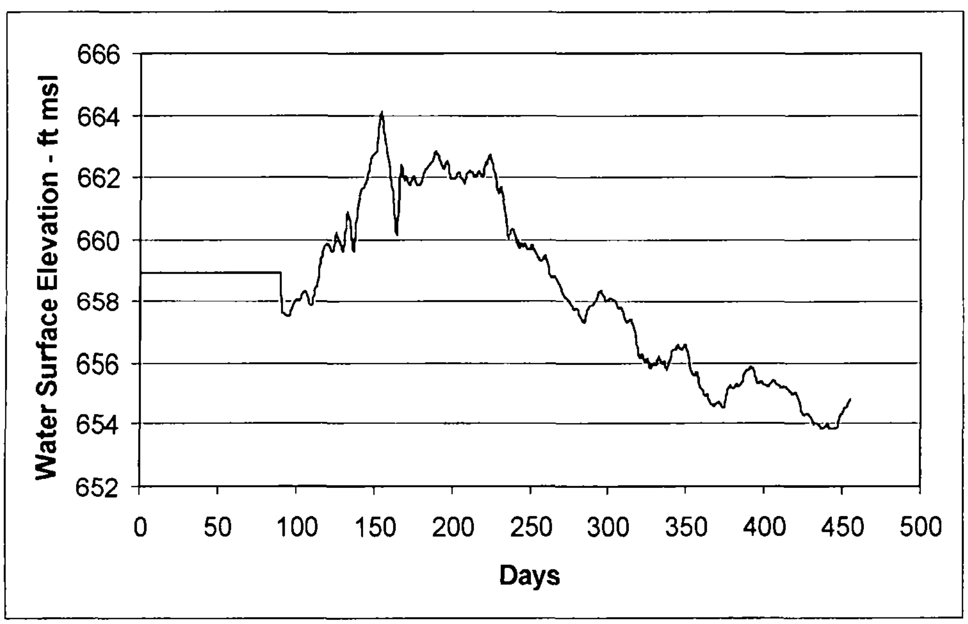

Figure 8 Downstream stage boundary at transect T6 – initial 90 day mean stage of 659 ft msl with the 1990 yearly stage hydrograph

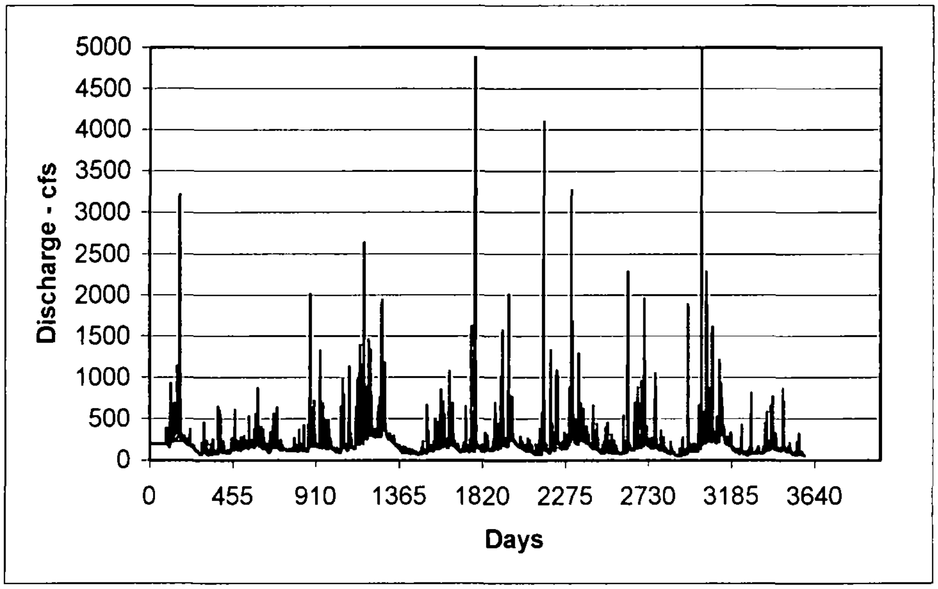

Figure 9. Upstream flow boundary condition at Liberty Bridge for the Easley Central dam removal scenario – initial 1.25-year flow plus a nine-year hydrograph (1991 – 1999)

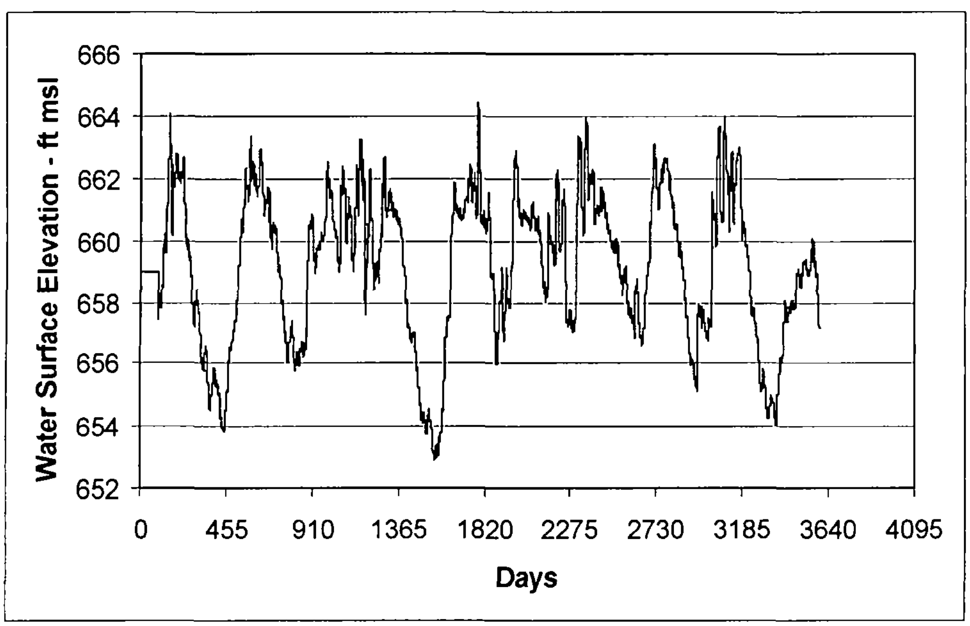

Figure 10. Downstream stage boundary at transect T6 for the Easley Central dam removal scenario – initial 1.25 year stage plus a nine year stage hydrograph (1991 – 1999)

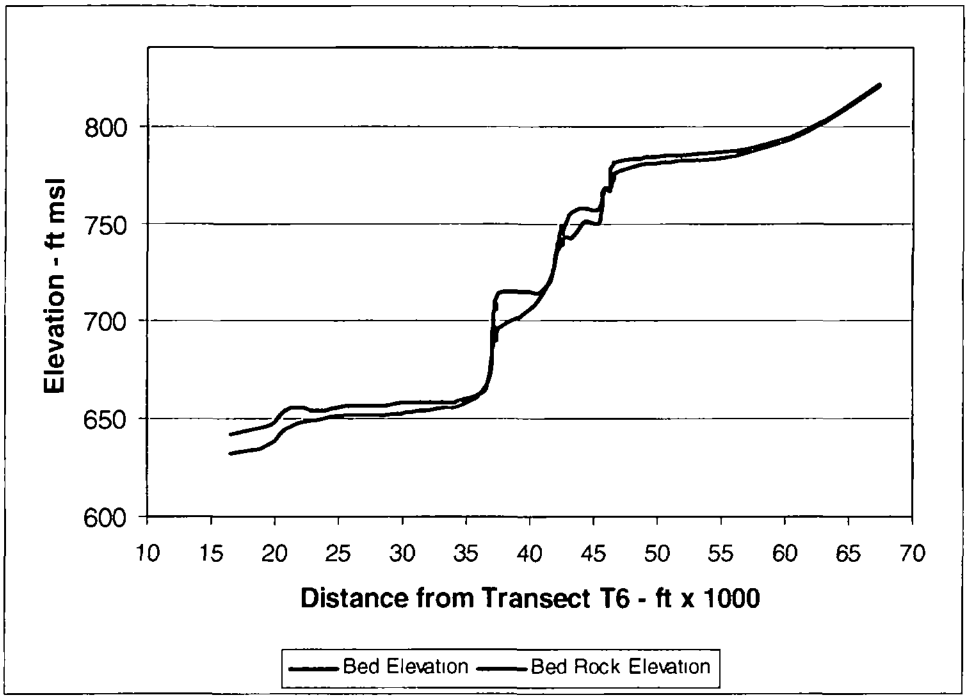

Figure 11. Pre-simulation bed and bedrock elevation profile: transects O – Liberty Bridge

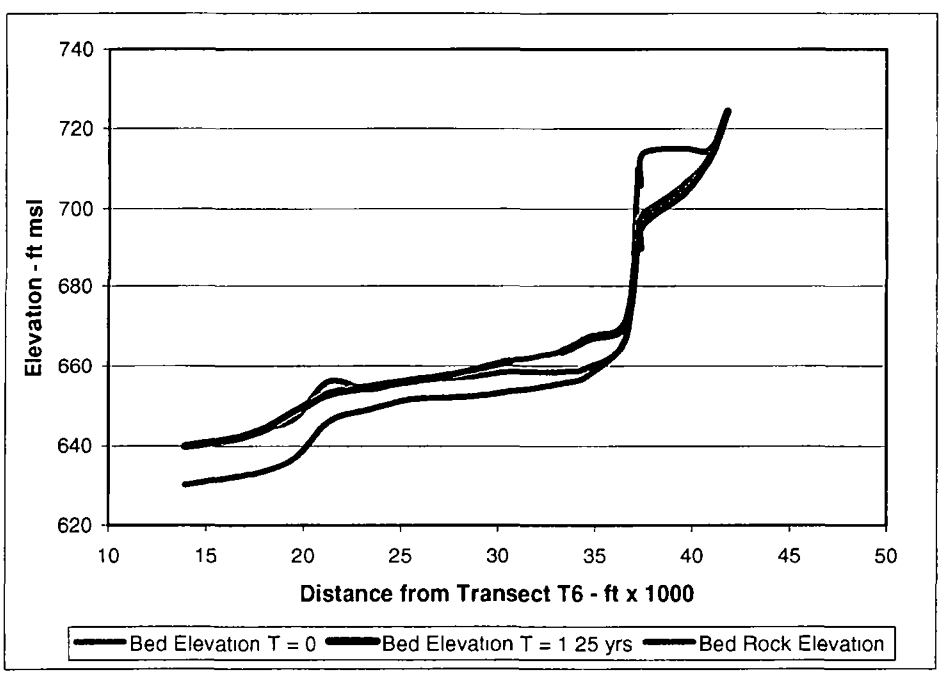

Figure 12. Woodside II dam removal simulation: pre and post simulation bed and bedrock elevations: transects N – 4C

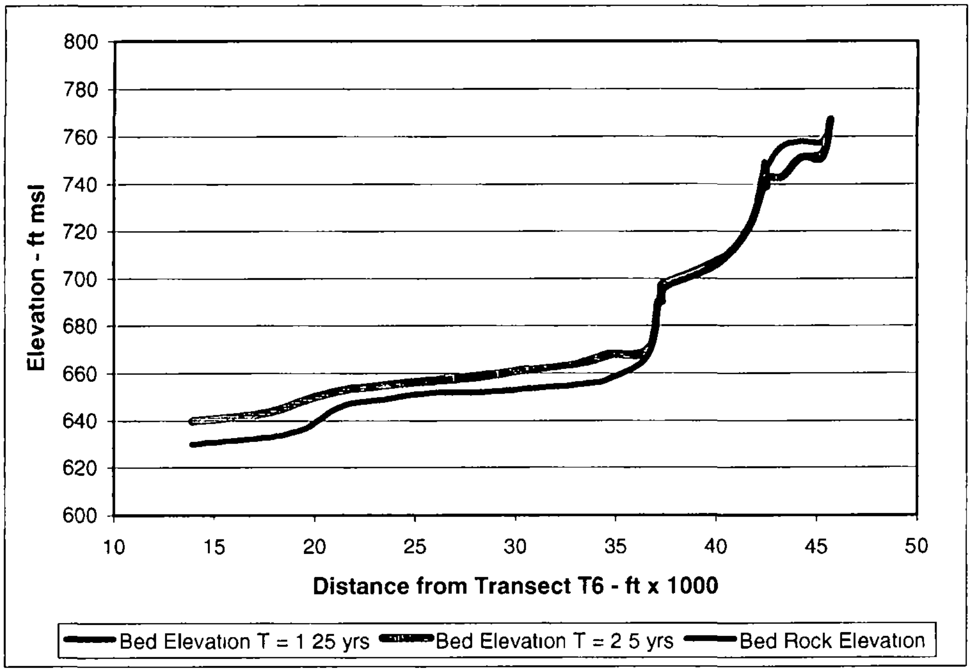

Figure 13. Woodside I dam removal simulation: pre and post simulation bed and bed rock elevations: transects N – 8C

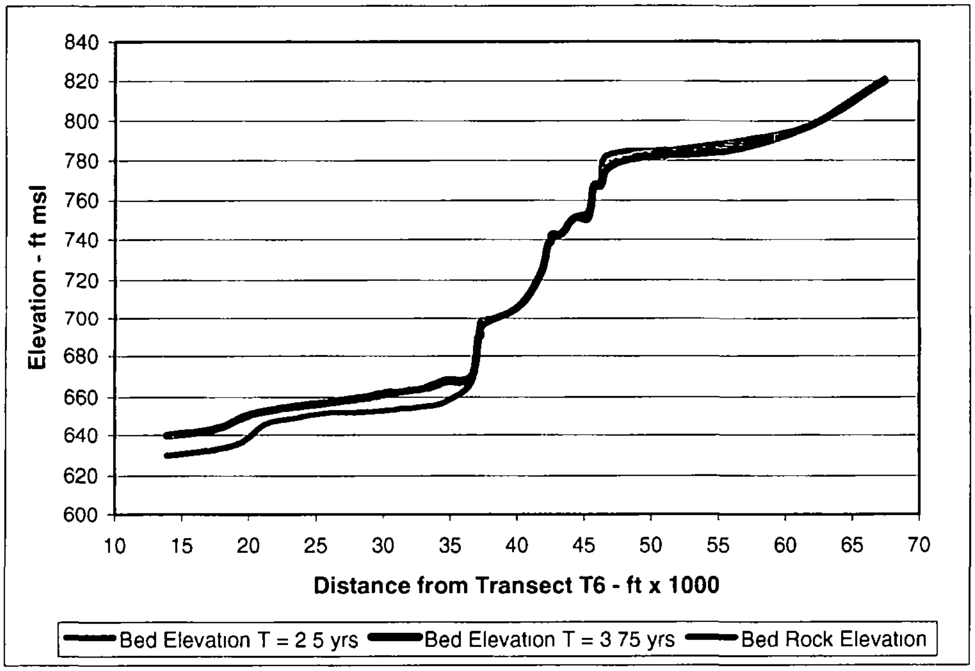

Figure 14. Easley Central dam removal simulation: pre and post simulation bed and bed rock elevations: transects N – Liberty Bridge

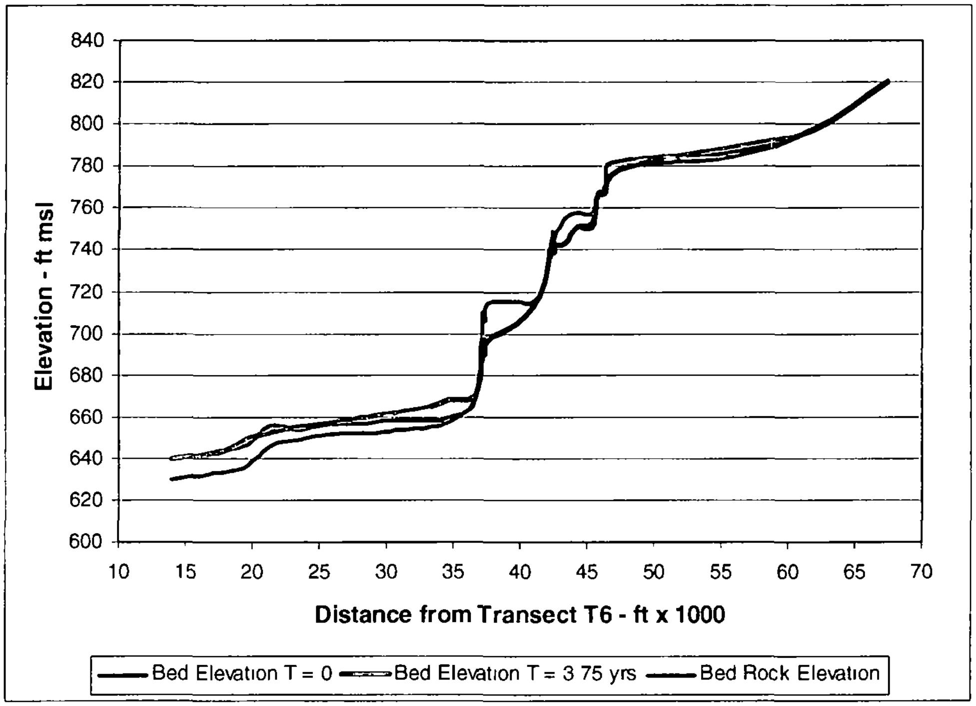

Figure 15. Pre and post simulation bed and bed rock elevation: all dams removed: transects N – Liberty Bridge

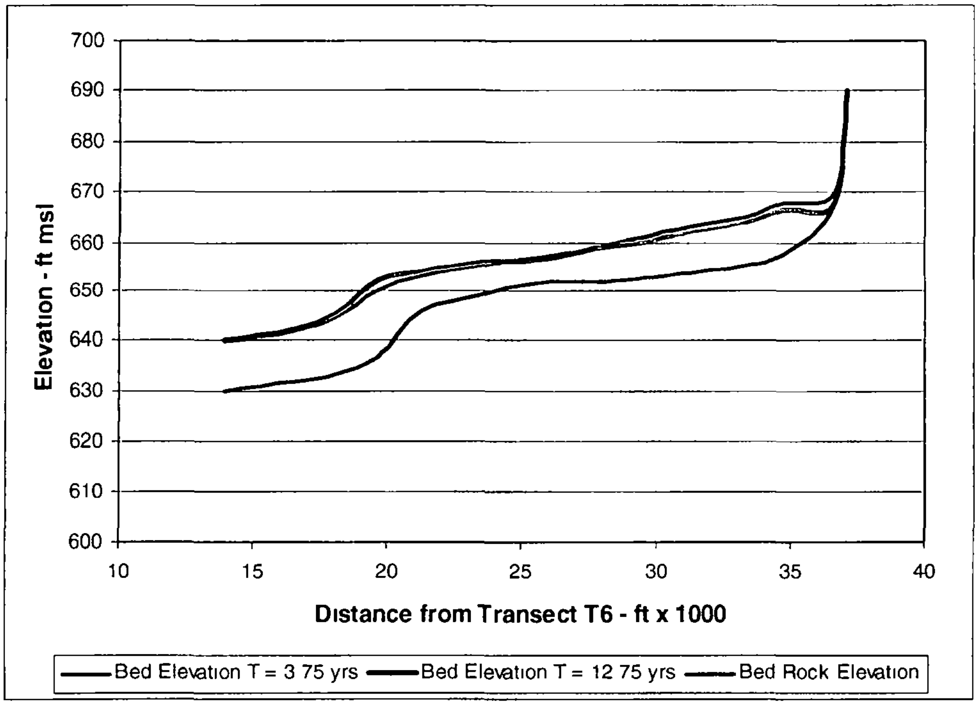

Figure 16. Bed elevations below Woodside II after 3.75 and 12 75 years: transects N – T19

APPENDIX A

CHANGE IN BED ELEVATION FOR CHANNEL
SEGMENTS 1 – 3 AFTER WOODSIDE II REMOVAL
T = 0, 90, AND 455 DAYS

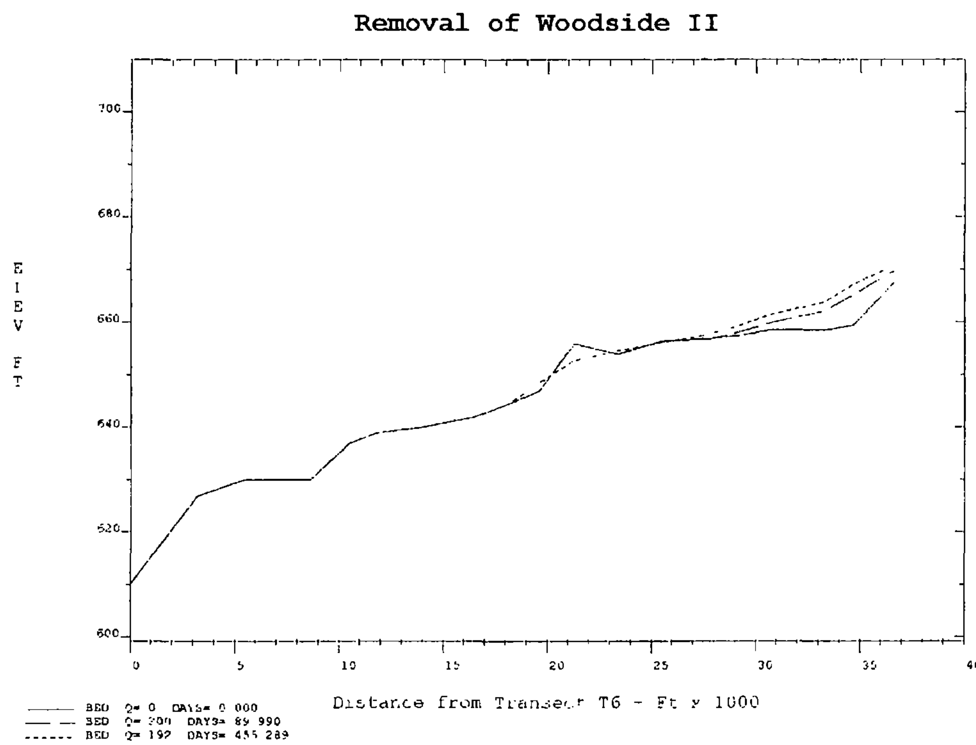

Figure 1a. Change in bed elevation for channel segment 1 after removal of Woodside II

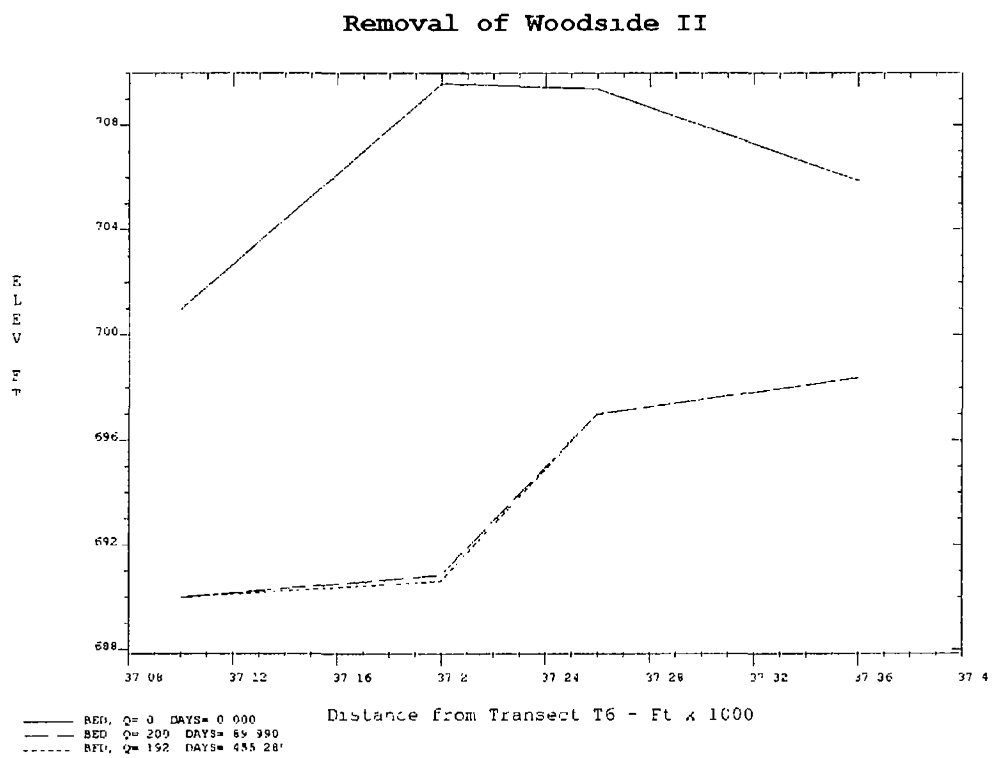

Figure 2a. Change in bed elevation for channel segment 2 after removal of Woodside II

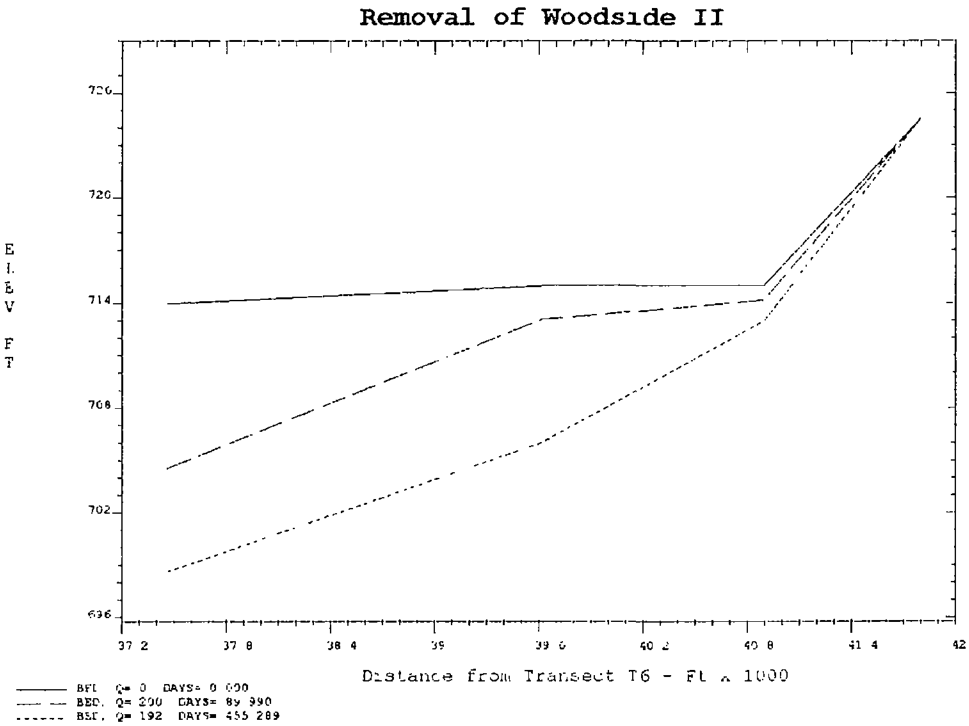

Figure 3a. Change in bed elevation for channel segment 3 after removal of Woodside II

APPENDIX B

CHANGE IN BED ELEVATION FOR CHANNEL
SEGMENTS 1 – 5 AFTER WOODSIDE I REMOVAL
T = 0, 90, AND 455 DAYS

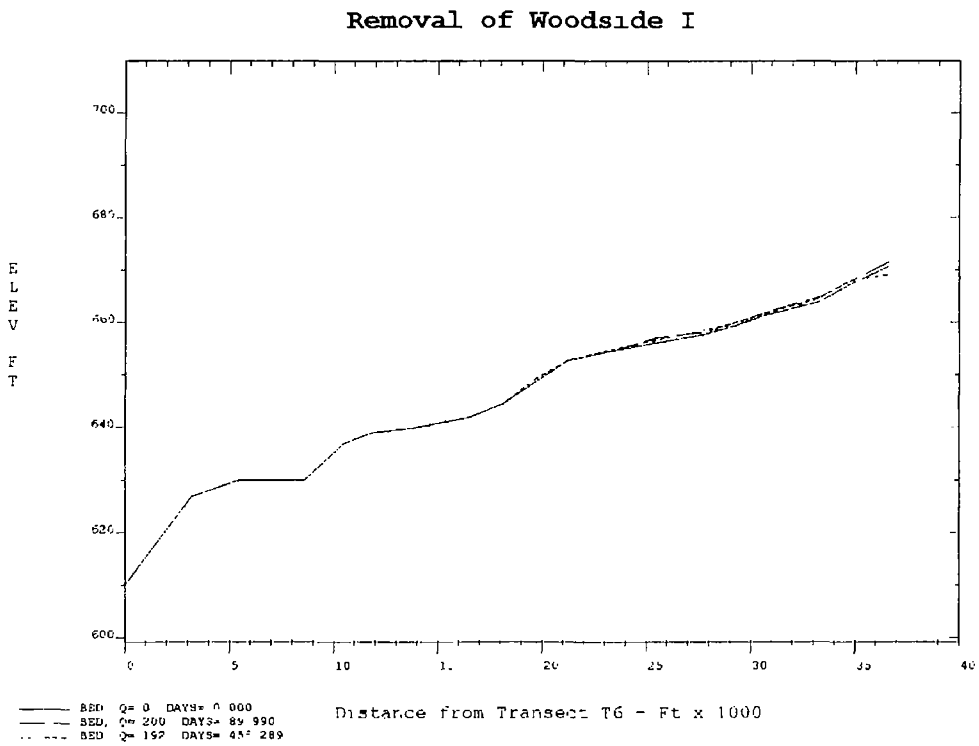

Figure 1b. Change in bed elevation for channel segment 1 after removal of Woodside I

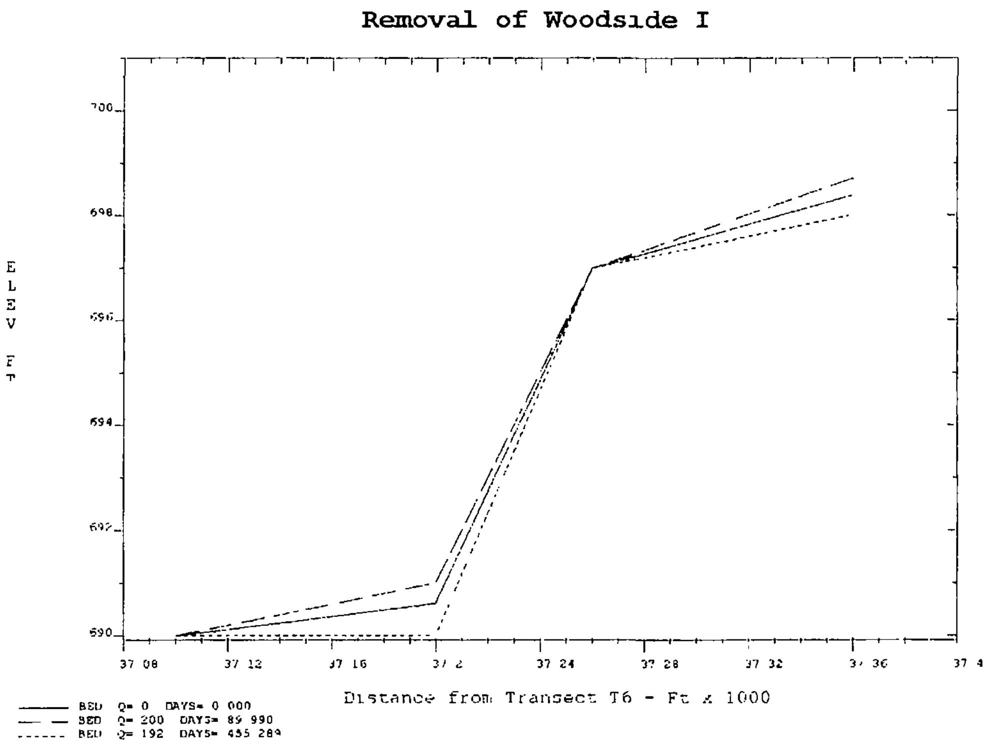

Figure 2b. Change in bed elevation for channel segment 2 after removal of Woodside I

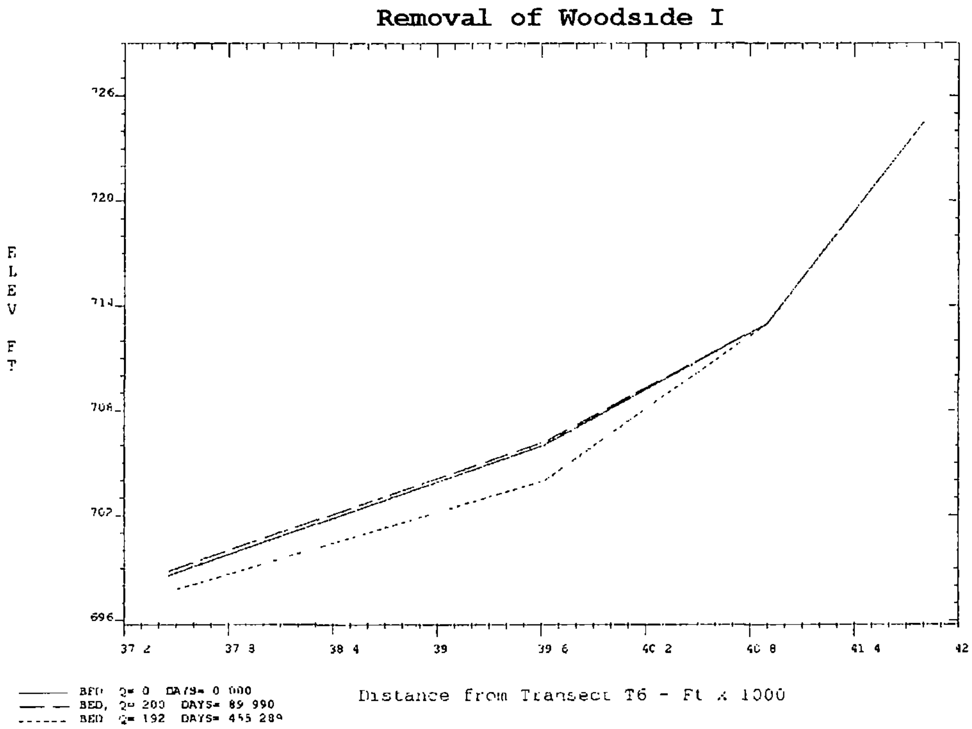

Figure 3b. Change in bed elevation for channel segment 3 after removal of Woodside I

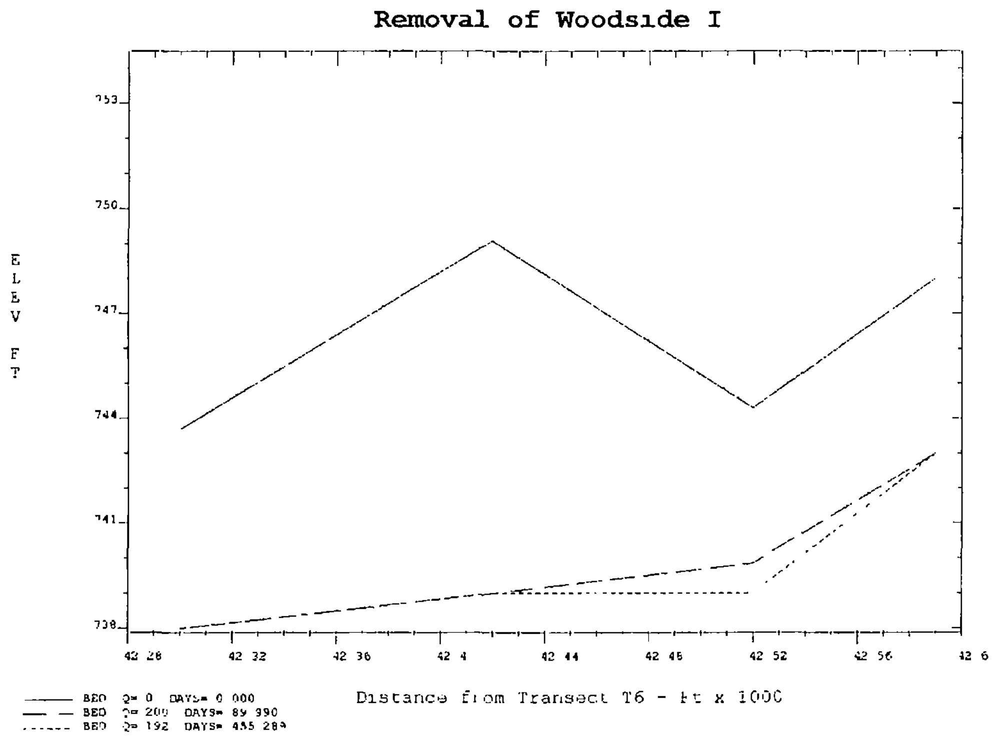

Figure 4b. Change in bed elevation for channel segment 4 after removal of Woodside I

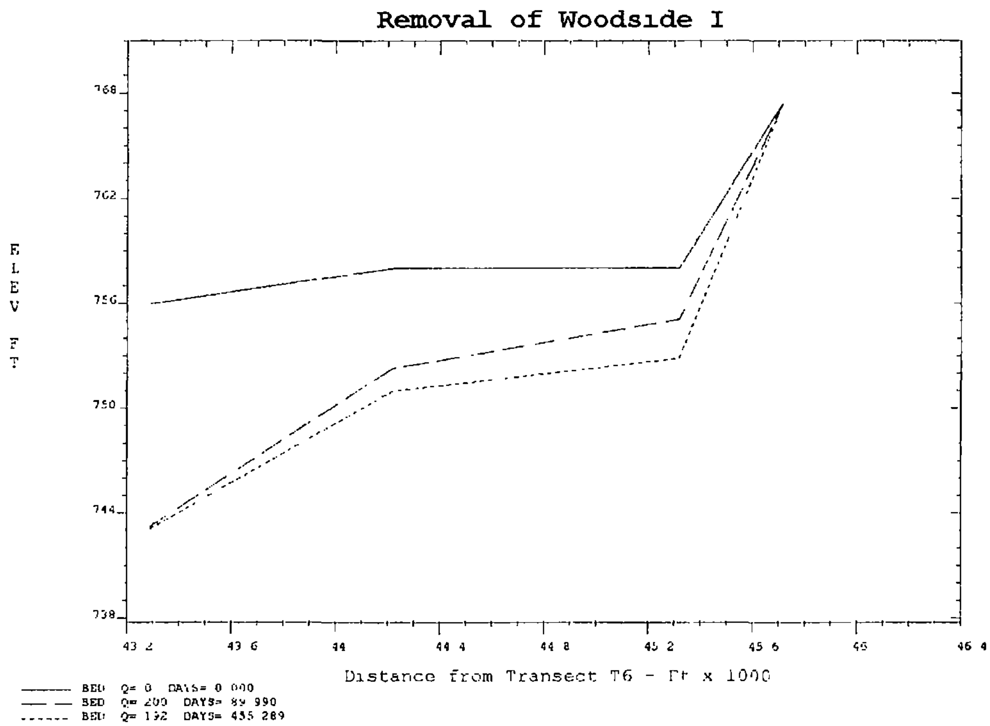

Figure 5b Change in bed elevation for channel segment 5 after removal of Woodside I

APPENDIX C

CHANGE IN BED ELEVATION FOR CHANNEL SEGMENTS 1 – 7 AFTER EASLEY CENTRAL REMOVAL T = 0, 90, AND 455 DAYS

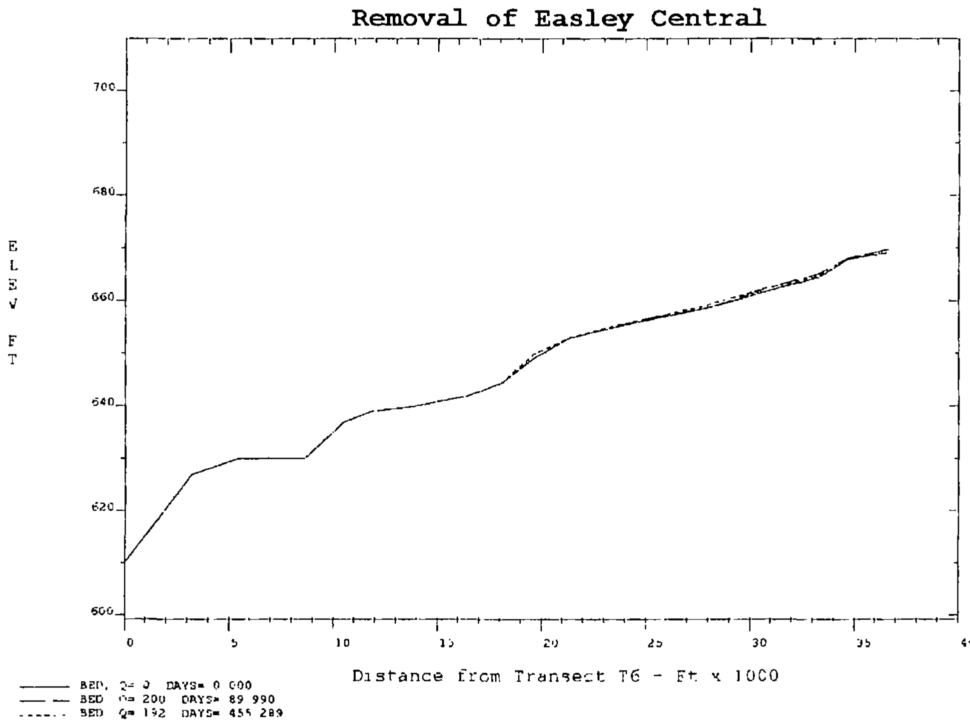

Figure 1c. Change in bed elevation for channel segment 1 after removal of Easley Central

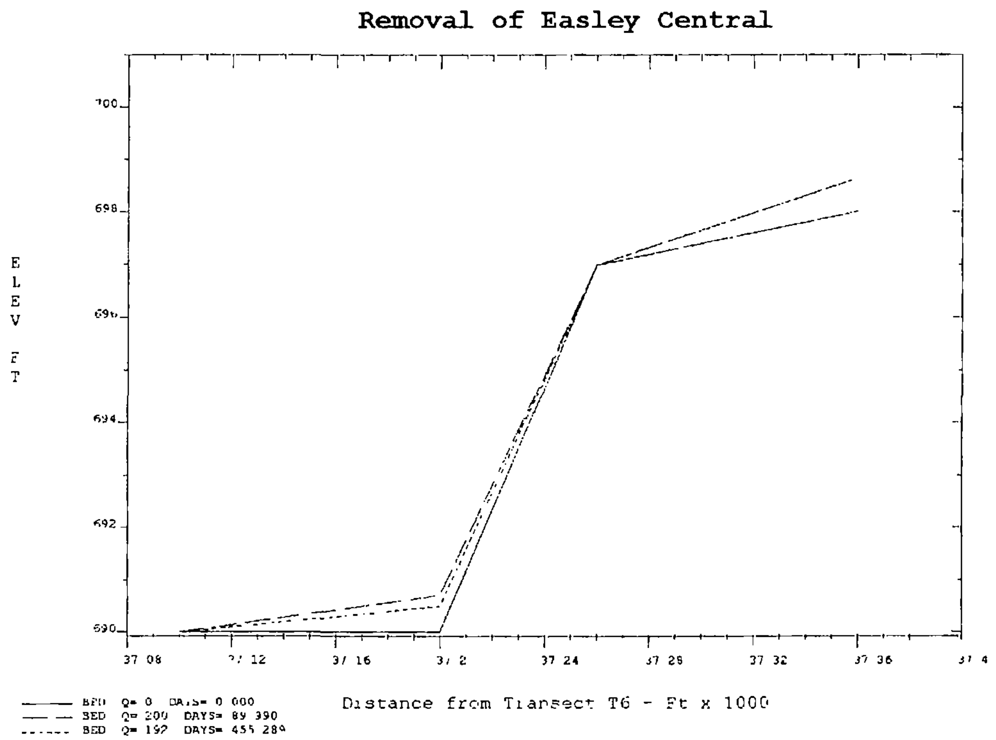

Figure 2c Change in bed elevation for channel segment 2 after removal of Easley Central

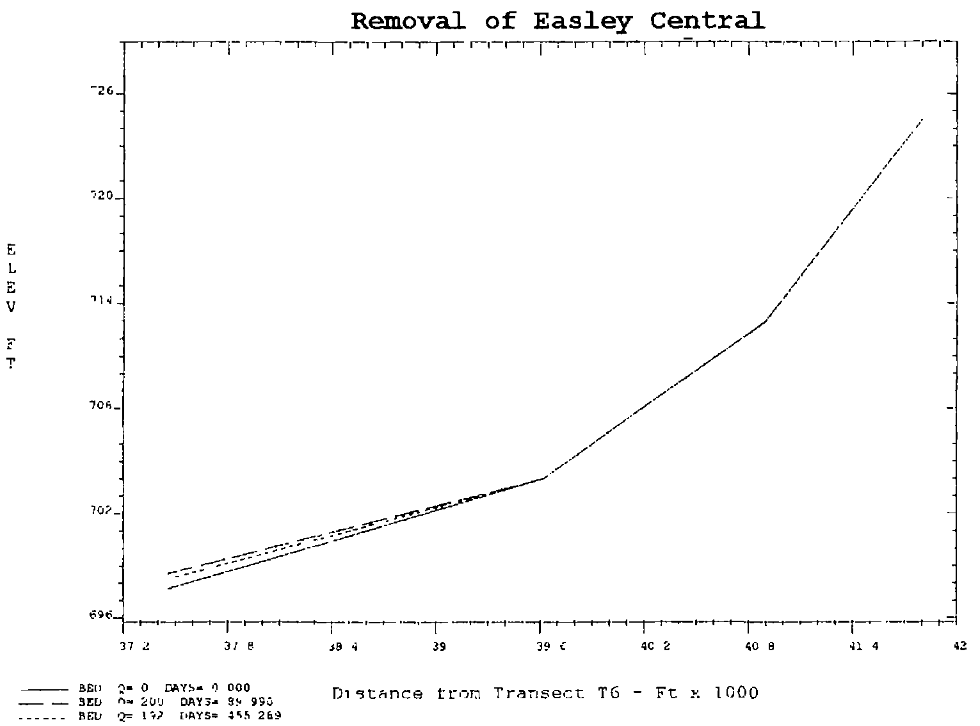

Figure 3c. Change in bed elevation for channel segment 3 after removal of Easley Central

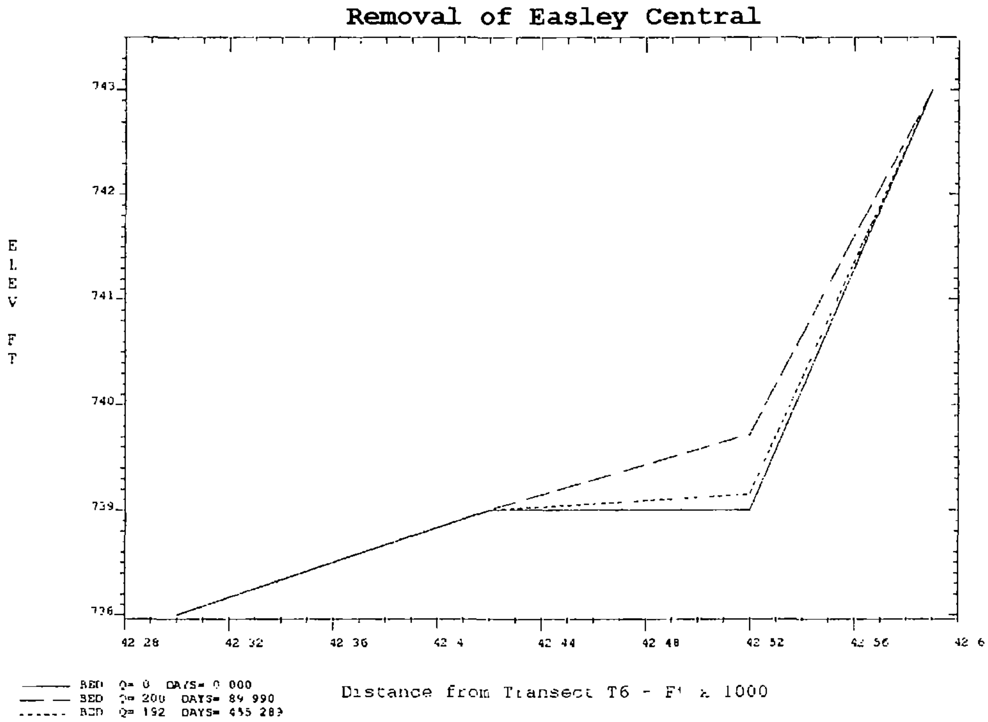

Figure 4c. Change in bed elevation for channel segment 4 after removal of Easley Central

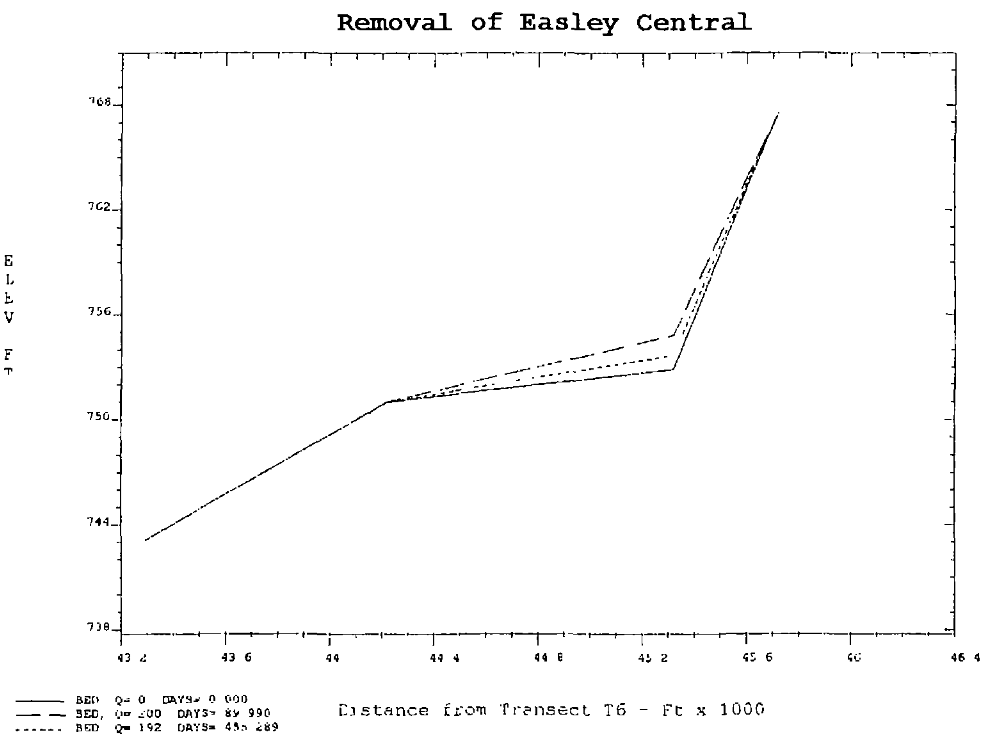

Figure 5c Change in bed elevation for channel segment 5 after removal of Easley Central

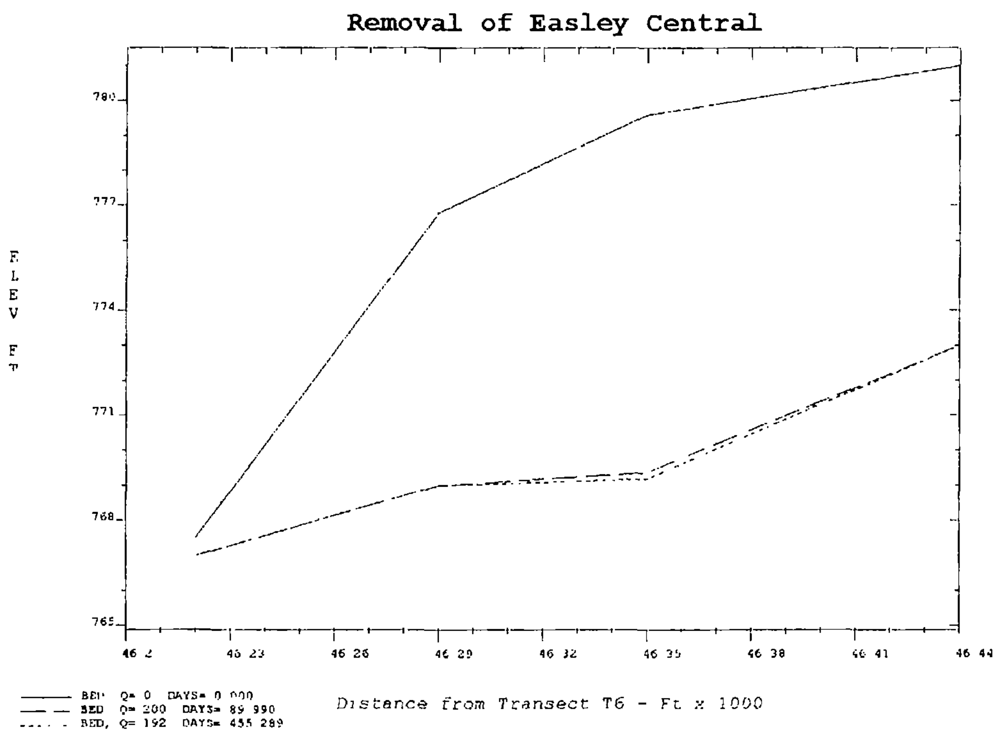

Figure 6c. Change in bed elevation for channel segment 6 after removal of Easley Central

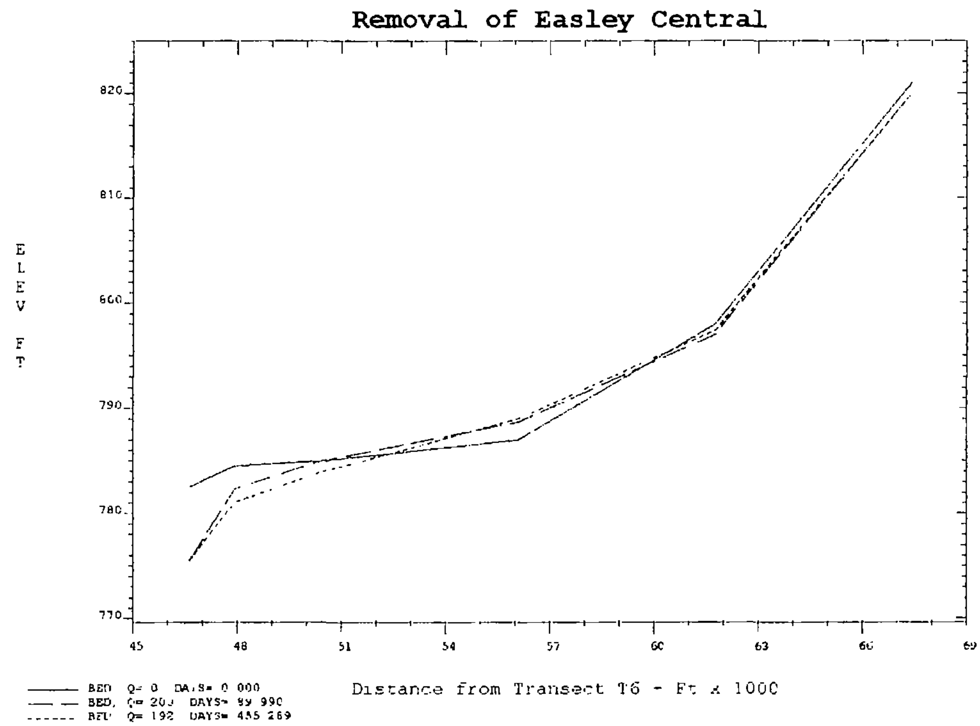

Figure 7c. Change in bed elevation for channel segment 7 after removal of Easley Central